

operations associated with the method 400. Although illustrated with discrete blocks, the steps and operations associated with one or more of the blocks of the method 400 may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the desired implementation.

[0051] At block 405, a VPP (e.g., the VPP 110 of FIG. 1) with a solar power generating device (e.g., the solar power generating device 112 of FIG. 1) and at least one non-solar power generating device (e.g., any one of the wind power generating device 113, the fossil fuel power generating device 114, or the hydro power generating device 115 of FIG. 1) may be used to generate electrical power.

[0052] At block 410, a test dataset of historical irradiance data at the location of the solar power generating device may be obtained. The block 410 may be similar to the block 315 of FIG. 3.

[0053] At block 415, the test dataset may be normalized based on a clear sky model of irradiance at the location of the solar power generating device. Such normalization may include dividing the irradiance of a data point at a given time of day by the typical irradiance during a clear sky at a given time of day for each historical data point in the test dataset. Such normalization may be performed by a control device (e.g., the control device 111 of FIG. 1).

[0054] At block 420, a histogram of the test dataset may be plotted. For example, a plot such as the plot 210 of the example set of plots 200 of FIG. 2 may be generated based on the normalized test dataset. Such plotting may be performed by the control device.

[0055] At block 430, a histogram curve may be fitted to the histogram. An example of such a curve may include the curve 225 of the plot 220 of FIG. 2. The histogram curve may include a combination curve that includes the combination of class-specific curves. For example, there may be a curve corresponding to each of multiple weather classes to which the test dataset may be clustered. Examples of such classes may include overcast, partly cloudy, or clear. An example of such curves may include the first, second, and third curves 232, 234, and 236 of the plot 230 of FIG. 2. Such fitting may be performed by the control device.

[0056] At block 435, the data points in the test dataset may be clustered into one of the classes. In some embodiments, each of the classes may include a corresponding set of characteristics. In these and other embodiments, each data point in the test dataset may be clustered into a weather class based on how closely a given data point fits to the curve associated with a particular weather class. As another example, multiple characteristics may be considered, and each data point may be classified based on an analysis of similarities of the data point with multiple characteristics of the set of characteristics of a given weather class. Additionally or alternatively, the characteristics may be weighted in a non-uniform way such that one or more characteristics may have a predominant effect on whether a given data point in the test dataset is clustered into a given weather class. The control device may perform such a clustering.

[0057] At block 440, a forecast of irradiance may be obtained. The block 440 may be similar to the block 330 of FIG. 3.

[0058] At block 445 (illustrated in FIG. 4B), a nearest neighbor of the forecast in the test dataset may be found. For example, the control device may find the data point in the test dataset that is most similar to the forecast. Such a finding

may include consideration of multiple characteristics of the forecast and the data points in the test dataset. In some embodiments, one or more of the characteristics may be weighted more or less than other characteristics in finding the nearest neighbor of the forecast.

[0059] At block 450, the forecast may be classified into one of the weather classes based on the nearest neighbor. For example, the forecast may be placed in the same weather class as the nearest neighbor. Additionally or alternatively, a subset of weather classes may be selected based on the nearest neighbor and the characteristics of each of the subset of weather classes may be compared to the characteristics of the forecast. The classification may be performed by the control device.

[0060] At block 455, a confidence interval of the forecast may be determined. The block 455 may be similar to the block 340 of FIG. 3. At block 460, a determination may be made as to whether the confidence interval is larger than a threshold. The block 460 may be similar to the block 345 of FIG. 3.

[0061] At block 465, after a determination that the confidence interval is larger than the threshold, operation of the VPP may be modified. For example, the output of the solar power generating device may be decreased and the output of the non-solar power generating device may be increased. In some embodiments, such an increase and/or decrease may be proportional to the confidence interval.

[0062] At block 470, after a determination that the confidence interval is not larger than the threshold, operation of the VPP may be modified. For example, the output of the solar power generating device may be increased and the output of the non-solar power generating device may be decreased. In some embodiments, such an increase and/or decrease may be proportional to the confidence interval.

[0063] Accordingly, the method 400 may be used to operate a VPP that includes a solar power generating device. Modifications, additions, or omissions may be made to the method 400 without departing from the scope of the present disclosure. For example, the block 405 may be omitted. As another example, the operations of the method 400 may be implemented in differing order. Additionally or alternatively, two or more operations may be performed at the same time. Furthermore, the outlined operations and actions are only provided as examples, and some of the operations and actions may be optional, combined into fewer operations and actions, or expanded into additional operations and actions without detracting from the essence of the present disclosure.

[0064] By way of example, certain aspects of at least one embodiment of the present disclosure may be described with reference to equations and/or mathematical operations. For example, the analysis to describe the future probability distribution of solar power from historical data may be described as

$$P(y_{t+h}-y^*_{t+h}|x_t)$$

where y_{t+h} may represent the true forecast value at $t+h$; y^*_{t+h} may represent a forecast at $t+h$; $x_t=(Y_t, Z_{t+h})$, where $h=\{1, \dots, H\}$; and $Y_t=\{y_1, \dots, y_t\}$ may be a vector of analog observations prior to and including time t ; and $Z_{t+h}=\{z_1, \dots, z_t, z_{t+h}\}$ may be a vector of analog exogenous variables prior to and including time $t+h$; and for n number of weather information variables, $z_i \in \mathbb{R}^n$ where $i=1, \dots, t+h$.